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Neuromyths in the Light of the Theory of Systemic-Dynamic Brain Organization of Mental Functions

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Нейромифы в свете теории системно-динамической мозговой организации психических функций

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Abstract. Knowledge about brain functioning is important for many professionals, especially in the fields of medicine and education, but for a wide audience as well. Neuromyths are false (completely or partially) simple and seemingly logical statements about the anatomy or functioning of the human brain. This paper presents typical sources of such errors such as misinterpretation, oversimplification, or overgeneralization. Special attention is given to analysis of some examples of the long-established source of misconceptions — regarding functional asymmetry of brain hemispheres, to the myth of the triune brain, and the so called "Mozart effect" from the point of view of the Lurian systemic-dynamic approach to brain functions.

Keywords: *brain development; neuromyths systemic-dynamic approach; Mozart effect; triune brain; interhemispheric asymmetry*

Аннотация. Знания о функционировании мозга важны не только для профессионалов, работающих в области медицины и образования, но также и для широкой аудитории. Нейромифы — это полностью или частично ложные, упрощенные но, казалось бы, логичные утверждения об анатомии или функционировании человеческого мозга. В этой статье представлены типичные источники таких ошибочных представлений: неправильное толкование, чрезмерное упрощение или чрезмерное обобщение. Особое внимание уделяется анализу некоторых примеров давно известных заблуждений — мифов о функциональной асимметрии полушарий мозга, мифе о триедином мозге и так называемом «эффекте Моцарта» с точки зрения системно-динамического подхода к функционированию мозга А. Р. Лурия.

Ключевые слова: *развитие мозга; нейромифы; системно-динамический подход; триединый мозг; «эффект Моцарта»; межполушарная асимметрия*

Introduction

Neuromyths are false (completely or partially) statements about the anatomy or functioning of the human brain and their influence on human behavior, mostly aimed to explain individual differences in behavior. Usually such statements are appealing to common sense simple and seemingly logical, but their logic is similar to the claim that the earth is flat. Though there is no evidence for their truth, and even very often disproof, these false ideas used as a basis for pedagogical or rehabilitation recommendations, which divert precious time and money from those who are in need of real evidence-based help.

Cambridge researcher Usha Goswami is concerned with neuroscience application to education:

> Cognitive neuroscience is making rapid strides in areas highly relevant to education. However, there is a gulf between current science and direct classroom applications. Most scientists would argue that filling the gulf is premature. Nevertheless, at present, teachers are at the receiving end of numerous 'brain-based learning' packages. Some of these contain alarming amounts of misinformation, yet such packages are being used in many schools. (Goswami, 2006, p. 406)

This is perhaps a global problem, because the theme of neuromyths in teachers' education, knowledge and practice has recently become subject matter for research and publications in many countries: USA, Canada, Greece, Spain, Britain, Ireland, the Netherlands, Turkey, China, Russia, Austria (Grospietsch & Mayer, 2020; Howard-Jones, 2014; Papadatou-Pastou, Haliou, & Vlachos, 2017; Van Dijk & Lane, 2020).

Some widespread misconception in much of psychology about the brain, for example about evolution of the brain widely shared in introductory psychology textbooks, although long discredited among neurobiologists stands in contrast to the clear and unanimous agreement on these issues among those studying nervous-system evolution (Cesario, Johnson, & Eisthen, 2020).

Most widespread and long-lasting, especially among educators, are different myths related to "hemisphericity" inspired by Robert Ornstein who encouraged the use of different ways of teaching to stimulate the "creative" right brain versus our intellectual left brain. Arguing that modern society undervalues the right hemisphere's touchy-feely mode of approaching the world, dichotomizers touted fanciful simple schemes for boosting this hemisphere's activity. The followers of Ornstein in books and seminars promised to free us of the barriers to personal growth imposed by an inflexible school system that favors "left hemisphere thinking" (Lilienfeld, Lynn, Ruscio, & Beyerstein, 2009). Some educational texts encourage teachers to determine whether a child is left-brained or right-brained before they attempt to teach them (criticized by Howard-Jones, 2014).

As opposed to neuromyths, neurofacts are results and conclusions based on researches of structure and functions of the human brain in relation to human behavior. Often neuromyths are based on wrong interpretation of neurofacts or oversimplification of facts, using some hypothesis which is still unproved or reported in an inaccurate investigation, or incomplete information. Professional scientists are immunized against neuromyths by knowledge of neurofacts and the theory underlying them, their own critical thinking protecting them from false declarations. The Lurian theory of systemic-dynamic approach to brain organization of higher mental processes seems to be the proper base for developing such a protection and we will try to critically analyze three popular neuromyths from the point of view of this theory. We choose to focus on the following myths: some aspects of the hemisphericity myths; the triune brain myth and the "Mozart effect" myth.

Human Interhemispheric Cooperation: From Myths to Facts

The subject of brain functional asymmetry historically is the source of many myths. It started from the mid-nineteenth century with the idea of hemispheric equipotentiality. The root of the idea can be found in the book of Arthur Wigan *The Duality of Mind* (1844). For twenty years he gathered and described cases of patients with seemingly normal behavior, though they had damage to one of the hemispheres to the extent of practical inactivity. He concluded that the patients' activity was possible because the two hemispheres are equal and each one is completely capable of regulating all mental life, like two eyes: each eye is self-sufficient, but when working together they can see better.

As an additional indication of the existence of two minds controlled by two hemispheres he took from cases of *split personality* and the fact that it is normal for people to conduct *an inner dialog,* as if discourse between ego and alter-ego, while each one is based in its own hemisphere.

Analysis of Wigan's logic is useful for understanding how wrong thinking can lead to myths and intermittently to laterality booms in education.

Wigan started from the simple and potentially verifiable declaration that with damage to one of the hemispheres mental life can remain complete by means of the other hemisphere. Describing examples, he did not mention which hemisphere was damaged at what age and how the activity was assessed and concluded that there is duplication. Referring to functioning of two eyes he ignored the fact of both right and left semi visual-field representations in each hemisphere to make each eye self-sufficient. He saw education as a source of developing harmony, although he suggested that "the willpower" of one hemisphere is "tyrannizing" over the other. Usually the left one is stronger and that is why the right hand is more effective as an instrument of will (Wigan, 1844).

It occurred that the idea of equality and parallel independent functioning of hemispheres was so attractive for common opinion especially among educators that this myth revived more than once even much later.

Discoveries of P. Broca (1861), and C. Wernicke (1875) of speech disorders following damage to the left hemisphere of the human brain marked the beginning of development of a scientific approach to brain functioning. Aphasiology may be considered as a first step to modern neuropsychology, in which attention was focused on the role of the left hemisphere in language and speech functions. Moreover, I. Boulloud (1865) associated aphasia due to damage of the left hemisphere with the fact that most people are right-handed. In some cases, damage to the right hemisphere in lefthanded patients caused aphasia, so called crossed aphasia (Bramwell, 1899).

Thus, the *conception of dominance of the left hemisphere* was formulated with a *conjunction hypothesis*, suggesting connection of handedness with hemispheric dominance with special attention to the manual dominance. This conception supposed that the *left hemisphere is dominant for all main processes including speech, thinking and generally for intellectual life*.

The conception of dominance became the basis of a new misconception and myths, and practical recommendations for parents and educators. An educational trend to promote left hemispheric dominance started and was one of the most long lasting.

Orton (1937) noted that some children having profound difficulties in reading and writing (but who otherwise were intellectually normal) showed frequent and prolonged confusion in directional orientation of letters and words. Many of these children were also "motor intergrades" that is their handedness was unclear: incomplete or mixed. Orton's remedial programs were highly individualized. He rejected any simplified and universally applicable formula, but his followers developed more rigid and simplified programs.

Because hemispheric dominance is related to handedness, attention must be paid to encouragement of right-handedness to avoid problems in development of speech and mental retardation. A negative attitude to left-handedness as a kind of "defect" had deep roots in religion and culture even earlier. In 1811 Mary Palmer Tyler published instructions on teaching infants "the right use of their hands." Recognizing, however, that left-handedness was hereditary "that it ran in families" she pronounced it no less natural than right-handedness and saw this as a reason why counteraction, although well intended, could be effective only in part. She also reassured parents that a child without this "natural defect" will never acquire it after birth, so that "all anxiety upon the subject is superfluous." But even where it appeared in a child not "born" with it, they would have had no reason to pay special attention to the child's hand use (Harris, 2010, pp. 7–9).

Though M. Tyler was so kind and reassuring for anxious parents, but after the establishment conception of dominance the usual practical recommendation for parents and caregivers was to promote right handedness. Some older lefthanders around us still can tell how their left hand was bound to their body to give the right hand an opportunity to develop writing skills. The attitude toward left-handedness gradually changed during the twentieth century. While at the beginning of the twentieth century there were only three per cent of lefthanders, up till the millennium a rather stable across countries and continents distribution was gradually formed: ten to twelve per cent lefthanders among men and nine to ten per cent among women (McManus, 2009). So, there is no longer any pressure on lefthanders, but there are different attempts to influence hemispheric functions for better cognition and academic achievements.

Back at the beginning of the twentieth century, as a reaction to the concept of dominance, almost immediately a conflict between two myths began: hemispheric equipotentiality versus the conception of left hemispheric dominance. The wide public interest in the functioning of the brain with a critical attitude toward handedness and propagation of ambidexterity can be found in many publications. In 1900 Doctor James Sawyer wrote: "I desire to join in recommending the general culture and adoption of ambidexterity… In our own manifold profession ambidexterity is a great equipment. In laryngoscopy, in ophthalmoscopy… in examination *per vias naturales* it is useful" (Sawyer, 1900, p. 1303). *The Ambidextral Culture Society and the Duality of Mind* (Harris, 1985) was established with a propaganda — the equal training of right and left hands in the arts and crafts of the day, as stated in the book of the founder of this society John Jackson (1905) *Ambidexterity, or Two-Handedness and Two-Brainedness*. He considered that one handedness is an artifact of civilization and inspired a reform movement in education (Harris, 1985). This idea was immediately criticized by a more informed professional doctor N. Harman:

> …ordinarily trained men are possessed of a real ambidexterity, or, as it would be better stated, co-ordination of bimanual action. It follows from this that the aim of the Ambidextral Culture Society is futile; mother nature has already done the work which this new society proposes, and done it so quietly and secretly and so delicately… (Harman, 1905, p. 16)

Harman also alerted against "cultivation of educational fads," but at the end of the 20th century his statement was still actual because educational fads were still appealing to hemispheric functions. In the 1970s a movement erupted: attempt to push our society out of our left brain thinking, and into a more intuitive, artistic right brain mode. Lauren Harris' comprehensive review is highly recommended (Harris, 1985).

The interest in human hemispheres is still very active. Two new different, though related myths can be found today on many different sites of the Internet.

One is related to the aging brain, the other is related to the developing brain, while looking for differences in functional asymmetry at different stages of life. There is a statement on the Internet: "Starting from age sixty people use two hemispheres for solving problems, *while young people use only one*" (for example here: Ovsianik, 2019). The site *Neuroscience News* has an intriguing caption: Children Use Both Brain Hemispheres to Understand Language, Unlike Adults (2020). Both declarations clearly proclaim that young adults use only one hemisphere, presumably the left one as they still embrace the conception of left hemispheric dominance and see advantage in lower asymmetry in children and aging people.

First of all, according to the systemic-dynamic approach to functional organization of the human brain, the problem of cerebral dominance in verbal processes appears not as an advantage or dominance of one over the other, but rather as description of a specific contribution of each to the complete verbal activity.

After publication of results of researches patients with bisected brain (Gazzaniga, 1970; Sperry, 1962) much attention was paid to functions of the right hemisphere in all aspects of mental functions and specifically to its role in language.

There are different sources of information about participation of the right hemisphere in verbal functions.

Today it is a well-established fact that the right hemisphere has an important role in language. In case of right hemisphere lesions in brain regions equivalent to Broca's area expressive language tends to be hasty, monotonous, lacking in prosody; there is a slight tendency to simplification of articulatory movements resulting in errors in syllables with complex phonetic combination (e.g. transport-tasport). Patients with right hemisphere lesions tend to use functional descriptions (circumlocutions), neologisms instead of correct names without hesitation or discomfort. When phonetic cues or names of the object are given to the patient, he points out the word or accepts the name, but without showing that he was having difficulty trying to find this name. There is also disautomatization in signature (Simernitskaya, 1974) and other problems of writing and reading (Ardila, 1984). The right hemisphere has an important function in modulation the affective component of the language through prosody and emotional gesturing (Ross, 1984).

Research dealing with verbal activity immediately after right- and left-sided electroshock seizures provided valuable material regarding the specific input of the right hemisphere. The right-sided electroshock seizure resulted in gross disorder of verbal behavior: while lexically and grammatically speech was normal, but the patients became overly loquacious, tending to give detailed description of improper details, pointless notes and commentary. They become unreasonably communicative intruding, giving advice. At the same time, they still have problems with voice and prosody (Balonov & Deglin, 1976).

In the foreword to the monograph of E.G. Simernitskaya (1978) A.R. Luria wrote in November 1975:

> Recent data reveal a need to depart from the simplified concept that one type (verbal) of process provided by just one, left (in right-handers) hemisphere, at the same time other (nonverbal) — only by right hemisphere.
>
> Psychological analysis reveals that practically all mental processes have complex functional organization because they can take place at different levels (voluntary and involuntary, conscious and unconscious, immediate and mediated). This provides a sufficient basis to suggest that there is an intimate interhemispheric cooperation, while the role of each one can change dependent on the task of a specific mental activity and its structure. (p. 6)

Such an approach is characteristic for Luria's disciples (Goldberg, 2009; Goldberg et al., 2013; Golod, 1984; Kotik, 1975, 1992; Kotik-Friedgut & Ardila, 2020; Simernitskaya, 1978, 1985).

According to the systemic-dynamic approach to functional organization of the human brain, the problem of cerebral dominance in verbal processes appears not as advantage or dominance one over the other, but rather as description of a specific contribution of each to the complete verbal activity. With such an approach we need to be especially cautious interpreting neuro-images not to retreat to localizationistic interpretations of signs or absence of signs of increased activation as basis for a far reached conclusion.

So, the claim that only one hemisphere is active in young adults is just a very rude simplification of the concept of hemispheric dominance. As to the facts of neuropsychology of aging there are many relevant publications, but none that referring to *"young people use only one"* (Ovsianik, 2019).

Brain Hemispheres in Aging

Older adults are generally slower in many aspects of activities. To maintain successful levels of performance during demanding cognitive tasks, they recruit compensatory mechanisms and strategies. Cognitive neuroimaging studies often report that older adults display more activation of neural networks than do younger adults. Such a situation is often referred to as *overactivation*.

Greater or more widespread activity frequently *involves bilateral recruitment* of both cerebral hemispheres, especially the frontal cortex.

This was the beginning of a new line of research of the aging brain. Further research revealed that the reduced asymmetry in fMRI is a result of compensatory activation of the right prefrontal region and it is more pronounced in subjects with better performance in memory tasks (Cabeza, Anderson, Locantore, & McIntosh, 2002).

The findings of fMRI examinations f show a broad pattern of *changes that support cognitive performance* in older adults' interhemispheric and intra-hemispheric reorganization. In tasks of different levels of demands on working memory older adults with higher working memory capacity demonstrated higher levels of network integration in the most difficult task conditions. Thus, age-related network reorganization suggests that changes in network connectivity may act as an adaptive form of compensation, with older adults recruiting a more distributed cortical network as task demands increase (Sala-Llonch et al., 2012).

There are several more models describing aging brain reorganization. The PASA (Posterior-Anterior Shift in Aging) model pays attention to posterior-anterior shift of activation due to involvement of frontal areas. This change is revealed in older subjects with tasks of different types and different levels of complexity (Crowell et al., 2020; Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008). With verbal semantic tasks this frontal involvement is clearer in the left hemisphere (Left Anterior-Posterior Aging effect — LAPA) thus revealing both inter-hemispheric and intra-hemispheric changes, in other words hemispheric reorganization of the aging brain (Hoyau et al., 2017). Special attention is given to age-related decreases in interhemispheric resting-state functional connectivity of symmetrical zones (Zhao et al., 2020).

Functional Asymmetry in the Developing Brain

Let us analyze the attention-grabbing statement that children unlike adults use both hemispheres on a site *Neuroscience News*, claimed to be based on a paper of neuroscientists from Georgetown University Medical Center ("Children use both," 2020; Olulade et al., 2020).

The study was focused on one task, language, and finds that to understand language (more specifically, processing spoken sentences), children use both hemispheres. The research revealed that while a large proportion of the youngest (mean age four and a half years) children show significant activation in their right hemisphere homologs of the left hemisphere language areas, this proportion decreases with age as does the right hemisphere activation itself. The fMRI pictures demonstrate no focused activation in the right hemisphere. It is also noted with reference to several sources that in healthy adults and stroke patients right hemisphere activation increases with sentence complexity, task difficulty and effortful performance. But in the present research there was no significant correlation between right hemisphere activation and task performance, suggesting that the right hemisphere activations "reflect genuine functional involvement of the right hemisphere in language processing and not an artifact of our specific task" (Olulade et al., 2020, p. 23480). It is claimed that the results of this study help to explain why despite early damage to the left hemisphere children can develop speech. While it is mentioned that the young brain is highly plastic, the authors hypothesize:

> The normal involvement of the right hemisphere homologs of language processes during very early childhood may permit the maintenance and enhancement of right hemisphere language development when the left hemisphere is injured. In this hypothesis, the declining involvement of the RH in sentence processing over development — and the increasing dedication of the RH homolog areas to processing other aspects such as prosody — may explain why language recovery after LH stroke is not as good in adults as it is in children. (Ibid, p. 23481)

So the focus of attention in explanation of functional changes over age is shifted from plasticity, which is mentioned only once, to a kind of plastic or dynamic laterality of language functions: from participation of the RH to LH dominance.

The site *Neuroscience News* takes it as a great discovery:

> Infants and young children have brains with a superpower, of sorts, say. Whereas adults process most discrete neural tasks in specific areas in one or the other of their brain's two hemispheres, youngsters use both the right and left hemispheres to do the same task. The finding suggests a possible reason why children appear to recover from neural injury much easier than adults. ("Children use both," 2020)

The problem of a possible process of compensation for brain damage in language development is the focus also of a group of researchers at the Swiss academy of Development. Karen Lidzba and her colleagues consider that pre- or perinatally acquired (congenital) left-hemispheric brain lesions can be compensated for by reorganizing language into homotopic brain regions in the right hemisphere. But it is important that they consider and emphasize in their approach that language comprehension may be hemispherically dissociated from language production (Lidzba, de Haan, Wilke, Krägeloh-Mann, & Staudt, 2017; Lidzba, Schwilling, Grodd, Krägeloh-Mann, & Wilke, 2011).

From the point of view of the systemic-dynamic approach it has to be s emphasized that the lifelong acquisition of cognitive skills shapes the maturation of the brain. In the study of Elisa Newport's group (Olulade et al., 2020) only a task of sentence comprehension was used. It is reasonable to propose that 13-year-old and adult subjects in the research were literate. We would like to mention acquisition of literacy as a factor which influences maturational dynamic changes of brain organization of higher mental functions.

There is enough evidence of influence of literacy on brain organization of language (Ardila et al., 2010). Castro-Caldas and Reis compared the repetition of auditorily presented words and pseudo-words in literate and illiterate women. The repetition of pseudo-words was significantly worse in the illiterate group than in the literate group. This difference was reflected in positron emission tomography images with a more bilateral involvement in illiterates (Castro-Caldas, Petersson, Reis, Stone-Elander, & Ingvar, 1998; Castro-Caldas & Reis, 2000). The acquisition of literacy transforms the human brain. By reviewing studies of illiterate subjects, Stanislas Dehaene and his colleagues propose specific hypotheses on how the functions of core brain systems are partially reoriented or recycled when learning to read. Literacy also modifies phonological coding and strengthens the functional and anatomical link between phonemic and graphemic representations. Literacy acquisition therefore provides a remarkable example of how the brain reorganizes to accommodate a novel cultural skill (Dehaene, Cohen, Morais, & Kolinsky, 2015).

Myth of the Triune Brain

In the 1960s, American neuroscientist Paul MacLean formulated the Triune Brain theory, which is based on the division of the human brain into three distinct regions. He started from research of brain regulation of visceral functions and coined the term *limbic system* (MacLean, 1955). But his later book *The Triune Brain in Evolution: Role in Paleocerebral Functions* (MacLean, 1990) became a source of one of the most popular neuromyths. It is so influential that most introductory psychology books published in the last decade presenting knowledge about brain evolution use incorrect information of MacLean (Cesario et al., 2020).

Along with neurofacts MacLean's book incorporated many insufficiently based interpretations. According to the theory of the triune brain the process of the brain's evolution resembles the geological development of the earth: new strata cover the old ones like the layers of the earth. According to MacLean, as a consequence of the appearance of new types of animals, new brain parts were added to the already existing ones. Most primitive and ancient parts, such as the spinal cord, brain stem, pons Varolii and middle brain, which are present in all animals, are responsible for survival. MacLean calls this arrangement the *Neural Chassis*. Upon this arrangement three executive layers or three "drivers" are built up, which regulate the chassis (each in its own way). The most ancient among the three is R-complex (reptilian complex). Reptilian brain comprised mostly of basal ganglia the newer are the limbic system (paleomammalian complex) and neocortex (neomammalian complex). Those three drivers are relatively *independent*, though widely cooperating. Each "executor" *is responsible for its' own type of behavior.* This responsibility is the result of brain evolution. Thus R-complex is the oldest and responsible for ritualized, stereotypic forms of behavior. After that the early mammals evolved the limbic system responsible for emotional and instinctive behavior and, finally, the neocortex of modern mammals is responsible for thinking. From the point of view of MacLean, human beings retain all these types of behavior and their functioning has changed very minimally since these three executors first appeared in the process of evolution.

The three main assumptions of MacLean's model are: the layering of evolutionary new executors upon old ones, the independence of executors from one another and their responsibility for specific behaviors, aroused a wave of discussions and criticism among specialists (Cory, 1999; Reiner, 1990). At the same time his ideas became very popular among non-professionals in neurophysiology. The popularity of the theory of the triune brain rocketed after publication of the book by Carl Sagan in 1977 *The Dragons of Eden*, which was reprinted many times (Sagan, 1977/2012). This is a nonacademic text (the author defined it as *Speculations on the Evolution of Human Intelligence*) and it is nearly impossible to differentiate facts about evolution of the brain from free speculations because of lack of references to sources and a lot of authoritative names of scientists. The reader even does not know that the author is not a professional involved in research in the theme he is presenting. He is professional in astrophysics and a kind of science interpreter but inspired by ideas of MacLean he writes about psychiatric disorders and a misbalance between three parts of the brain. Particularly he speculates about ritual components in psychiatric disorders as probable pathological activity in some center in the reptilian complex or inability of some part in the neocortex to inhibit or exclude this reptilian complex. He further discusses ritualized behavior of children and supposes that it results from incomplete development of the neocortex. Thus, he finds easy explanations for pathology: imbalance between reptilian and mammalian parts of the brain, while neuroscientists continue researches to find evidence-based solutions for real problems.

The false ideas of MacLean and his supporters influenced a tendency among modern psychologists to explain intrapersonal problems and conflicts based on the triune brain concept. Thus, egoistic or impulsive behavior may be explained as a dominance of reptilian or limbic behavior over the rest which gives seemingly "neuroscientific" interpretation of Freud's ideas about conscious, subconscious and unconscious parts of mind.

At her own webpage psychologist Susannah LaCombe (2020) writes: "If you're frustrated by your lack of progress in therapy, consider that the reptilian lizard part of your brain is holding you back. This primitive area of the brain controls much more of our behavior than we realize." Immediately she has a "prescription": "This is one of the key insights from body psychotherapy. When you calm the reptilian brain, you have more control over your emotions including your intentional behavior."

Other transmitters of MacLean's ideas may be found on YouTube. These include NY Times bestselling author and marketing expert Seth Godin lecturing about "How to overcome your 'lizard brain' to get ahead in your relationships and your career" (2019) and even neuroscientists such as Robert Sapolsky (2019) speaking about *3 Brain Systems That Control Your Behavior: Reptilian, Limbic, Neo Cortex*, etc.

Some popular trends in therapy such as Brain Gym® without confirmed value propose simple physical exercises for improvement of brain connectivity (Dennison P. E. & Dennison G. E., 1986; Spaulding, Mostert, & Beam, 2010). Such methods often are based on MacLean's ideas (Hannaford, 1995). The Brain Gym was deeply criticized by researchers who stand for evidence-based approaches in education and are fighting against neuromyths (Goswami, 2006).

Let us analyze the logic of MacLean from the point of view of the theory of systemic dynamic brain organization of mental functions.

The first of the basic assumptions of MacLean's model, the layering of evolutionary new executors upon old ones is perhaps the most criticized and refuted. His critics declare that his view was outdated even at the moment of the first publication of his book in 1989 and it was proven that not only mammals, but also reptiles and birds already have a limbic system and neocortex (Reiner, 1990). And MacLean's opponents' most important claim is that the evolutional line of mammals differs from that of reptiles and birds. That way the idea of layering of new brain structures of evolutionary newer species over the old ones is basically wrong (Cesario et al., 2020).

Moreover, much before the theory of MacLean appeared, there were enough data for a completely different approach to the evolution and functioning of the human brain. The roots of the systemic dynamic approach to organization of mental functions can be found in the book of Bernstein[1] (2003). As an example of changes of the system of visual perception in different species of animals, he formulated the following conclusions: appearance of new segments in the system leads to restructuring including new connections between structures, changes in old connections (often weakening or joining), delegation of the execution to the new more elaborated structures, while diminishing involvement of the old executive structures or even their cardinal change. At the same time the brain continues to function as a complete system — not as a complex of separate and partially independent systems which challenge each other in solving a specific problem. As an

[1] The book *The Modern Searches in the Physiology of the Neural Process* was written in 1935, but because of Soviet political restrictions it was forbidden; it was published only in 2003. For historical details see Sirotkina (2014).

example of such a process, N. Bernstein demonstrated that the tegmentum, which is the main brain part in fish, stops to be a part of for the processing visual signals in mammals. The visual tract in mammals goes to the primary visual cortex via the lateral geniculum, while only a narrow range of functions are preserved in the tegmentum, such as the regulation and control of pupillary reflex (Bernstein, 2003).

Evidently, similar changes normally occur in ontogenesis, when the brain systems for specific problem solving functions are replaced by more elaborately developed systems. The line in development goes from extreme disunity to redundant connectivity with low functional differentiation of specific brain areas to development of clear functional system of local zones that are more segregated and specialized (Annaz, Karmiloff-Smith, & Thomas, 2008; Farber, 2014). Another example: the control of the eye movement shifts from the subcortical structures to a complex system based on cooperation of occipital and frontal regions during development of the first 6 months. While prefrontal areas among other parts of the cortex are part of the visual perception, their reaction to sensory features of these stimuli is nonspecific until the age of 3–4 years and only at the age 6–7 do we find a frontal-specific reaction related to a more "adult" processing of visual information. These facts are clear evidence of the change of function of different brain structures at different stages of ontogenesis. Visual perception in adults is cardinally different from children: it does not demand a detailed analysis of the picture. Adult perception can start from using a very quick appraisal system (including the prefrontal cortex), putting forward hypotheses, which are "examined" and verified by slower systems of the visual cortex equipped for a more detailed analysis of visual images (Bar, 2003).

All facts described above demonstrate that not only the first idea of MacLean about layering new structures over the old ones was an error, but also show that the two other ideas about independence of the executive structures and preserving their evolutionary defined functions were similarly flawed. We clearly can see that the brain works as a concord and different structures can change their role in cognitive activities not only in a phylogenetic process, but also during ontogenesis.

The last two assumptions about independent executive centers are close to strict localizationism which was criticized by A. R. Luria. Sometimes the idea of the triune brain is mentioned alongside Luria's concept of three functional brain units, but the resemblance is very superficial. Some authors may see "The resemblances between MacLean's well known theory and Luria's lesser known theory are nothing short of remarkable. Luria's focus on the role of the sensory impulses (primitive neural structures) resembles MacLean's reptilian complex" (Kostyanaya & Rossouw, 2013, p. 54). The similarity is indeed superficial because according to Luria functional units are universal for all complex forms of mental functions (Luria, 1978). Such declarations, in spite of the fact that all Luria's neuropsychological works were immediately translated into English (and basic books in many other languages), motivate us to emphasize the difference between these two approaches and to publicize in the 21st century even more actively the relevance of basic ideas of Luria's systemic-dynamic approach for understanding the brain functions (Kotik-Friedgut & Ardila, 2020).

Luria's idea that each mental function is based on the integrative functioning of different brain regions united in brain functional systems has long become the fundamental idea of modern neuropsychology and cognitive neuroscience (Glozman, 2020).

Luria formulated the first "*law of hierarchical structure of the cortical zones. …*The relationships between the primary, secondary and tertiary cortical zones composing this system do not, of course remain the same, but *change in the course of ontogenetic development*" (Luria, 1973, p. 74).

According to Vygotsky (as cited in Luria, 1973), in development the interaction between the cortical zones goes "from below upward," meaning that defects of the lower zones in infancy must lead to incomplete development of the higher zones. By contrast, among adults the interaction goes "from above downward," and the tertiary zones then have a compensatory influence if the secondary zones are damaged (pp. 74–75).

According to the theory of systemic-dynamic organization of brain functions the changes of brain functions can be expected not only on such long-term phenomena as phylogenesis but even more so on ontogenesis. Brain organization of mental processes can be changed here and now, when the conditions of activity change. This is the basic idea in formulating neuropsychological rehabilitation via activation and involvement of intact brain areas for achievement of desirable cognitive results.

Thus, depending on the aim, seemingly the same operation can involve different brain mechanisms. For example, raising a hand may be realized and controlled differently if it happened as a result of fright, instruction to raise the hand, trying to reach a point (e. g. light switch), or to greet somebody. Such plasticity completely excludes any fixed rigid connection between a complex mental process and activity of some brain system which would make it impossible to adapt to changing conditions.

The Myth that Cognition may be Promoted through Listening to Music

One of the widely propagated neuromyths is the myth about the positive influence of Mozart's music on cognitive abilities, the so-called *Mozart effect*. The historical root of this myth is found in the results of the work of a group of researchers that revealed an increase of efficiency of spatial problem solving after ten minutes of listening to music (concerto No. 448 for two fortepianos), but the effect was absent after listening to music of composer-minimalist Philip Glass (Rauscher, Shaw, & Ky, 1993). They reported on their subjects' 8–9 units increasing of IQ, though the effect lasted only for a short time — 10–15 minutes. Later Frances Rauscher's group demonstrated that after eight months of music training (weekly electronic piano lessons and everyday singing lessons) 3–4-year-old children scored 34 % higher on the Object Assembly subtest from the Wechsler Preschool and Primary Scale of Intelligence — Revised (Wechsler, 1989) than children given computer or singing lessons or no training. The same day, Richard Knox (1993), a health, medicine, and science writer for The Boston Globe, reported the story in an article entitled *Mozart*

Makes You Smarter, Calif. Researchers Suggest. Knox called it the Mozart effect, the first to use this term, and other media picked up the story.

The effect was present already after four months music training (Rauscher et al., 1997). In this study there was no focus on Mozart (children learned to play simple melodies of Mozart and Beethoven), but the next results of the same group were even more impressive: spatial problem solving improved even in rats (Rauscher, Robinson, & Jens, 1998). In 1997, Don Campbell, a classically-trained pianist and teacher, published *The Mozart Effect*, the first in a series of books promising that listening to Mozart would, to quote its subtitle, not only "strengthen the [infant's] mind," it would "heal the body" and "unlock the creative spirit" (Campbell, 1997). Reports of the impressive impact of Mozart's music spread rapidly. Based on this myth, especially in the United States an immense market for Mozart-effect CDs or music toys targeted toward babies emerged to foster the intelligence of very young children (Düvel, Wolf, & Kopiez, 2017).

The results of Rauscher's group researches do not imply that listening to Mozart's music enriches human intelligence. A lot of questions still had to be addressed after these researches. For example, which specific characteristics of Mozart's music could influence spatial problem solving? Are there other types of stimuli with similar impact? Does music influence specifically spatial abilities or is the influence nonspecific (for example general activation)? For how long does the influence persist? If the effect can be seen only for several minutes or even hours, can it be concluded that Mozart's music can influence a child's development?

Attempting to replicate these results other researchers produced contradictory results: some came to similar conclusions, while others did not (Jenkins, 2001). Thus, one experiment repeated exactly the conditions of Rauscher's research, but their results did not confirm improvement in solving spatial problems after listening to Mozart's music (Steele, Bass, & Crook, 1999).

In 1999 the journal Nature published a discussion *Prelude or Requiem for the 'Mozart Effect'* (Chabris, 1999). The meta-analysis of 20 papers presented at the discussion failed to find any correlation between listening to Mozart's music and indexes of intelligence. Rauscher replied:

> Our results on the effects of listening to Mozart's *Sonata for Two Pianos in D Major, K. 448* on spatial-temporal task performance, have generated much interest but several misconceptions, many of which are reflected in attempts to replicate the research. The comments by Chabris and Steele et al. echo the most common of these: that listening to Mozart enhances intelligence. We made no such claim. The effect is limited to spatial-temporal tasks involving mental imagery and temporal ordering. (p. 827)

Later based on meta-analysis of nearly 40 studies, over 3000 subjects, the authors concluded that "on the whole, there is little evidence left for a specific, performance-enhancing Mozart effect" (Pietschnig, Voracek, & Formann, 2010, p. 314).

If we admit as true that a short-term Mozart effect exists, what would account for it?

Perhaps, at least partial explanation of a Mozart effect can be related to general activation triggered by audial stimulation. When describing principles of the first functional unit, which generally regulates activation, A. R. Luria illustrated the activating effect of stimulation of reticular formation on the cortex, evoking an arousal response as a result of a ringing bell sound awakening the cat. He emphasized the existence of two types of results in such stimulation: a *general activating effect on the cortex* and deep brain structures responsible for awakening via functioning of ascending reticular formation a kind of *non-specific activation,* which is distinguished radically from specific activation of the auditory cortex by its afferent connections via the thalamus, impelling the cat to turn and look at the ringing bell (Luria, 1973, pp. 48–58).

An experiment of researchers from Michigan University investigated the effect of music listening for performance on a 25-question portion of the analytical section of the Graduate Record Exam by 72 undergraduate students. Five levels of an auditory condition were based on approximately 6 minutes listening to a Mozart Piano Sonata; or a rhythm excerpt; or a melody excerpt; or traffic sounds; and silence. Participants were randomly assigned to one type of stimulus. After the listening period, participants answered the questions. Analysis indicated participants achieved significantly higher mean scores after all auditory conditions than did those in the silent condition. No statistically significant pairwise mean difference appeared between scores for the various auditory conditions. Findings were interpreted in terms of an arousal framework, suggesting the higher mean scores in all auditory conditions may reflect immediate exposure to auditory stimuli (Roth & Smith, 2008).

It means that the Mozart effect is not specifically related to Mozart's music or any music but is the effect of arousal as reaction to auditory stimulation.

Is it generally reasonable to expect that any musical training may influence development of cognitive abilities not related to music, such as a visual-spatial thinking as suggested by the Rauscher group (Rauscher et al., 1997)? There were attempts to explain such transfer pointing to the activation of allegedly identical brain areas while listening to music (Jenkins, 2001). Clearly such attempts are futile because they ignore the systemic-dynamic nature of any cognitive activity. According to Luria's systemic-dynamic approach to the brain's organization any mental function, especially higher mental activity (music listening is certainly human mental activity), cannot be localized in one or even several cortex areas. It is a complex widespread activity involving all three brain functional units, which is dynamic and influenced by changing conditions — internal as well as external. It is also incorrect to speak about a brain system of music listening or perception in general because music can be absolutely different according to rhythm (march or lullaby) according to emotional message (joyful or sad, major or minor) according to pitch, according to the sound of instruments, etc. In each case a specific dynamic functional system will develop. Accordingly, music can be a powerful tool in medical rehabilitation (Pauwels, Volterrani, Mariani, & Kostkiewics, 2014).

Recent meta-analysis of 54 researches selected according to rigorous criteria (experiment, control group, tests of cognitive (not musical) abilities of subjects, absence of any musical training and enough data to calculate effect) revealed the absence of any influence of musical training on cognitive abilities or academic skills. The higher the quality of experiment designs the lower the correlation of musical training and cognitive improvement of subjects. In addition to disproving the Mozart effect, these authors suggest that there is little or no probability of transfer of results of training in one skill on improvement of other far different abilities (Sala & Gobet, 2020).

Such an attempt was undertaken in a meta-analytic review to test if working memory training can improve performance on measures of intelligence or other measures of "far transfer." It has been claimed that working memory training programs produce diverse beneficial effects. A meta-analysis of working memory training studies (with a pretest-posttest design and a control group) that examined transfer to other measures (non-verbal ability, verbal ability, word decoding, reading comprehension, or arithmetic; Eighty seven publications with 145 experimental comparisons). Immediately following training there were reliable improvements in measures of intermediate transfer (verbal and visuo-spatial working memory). For measures of far transfer (nonverbal ability, verbal ability, word decoding, reading comprehension, arithmetic) there was no convincing evidence of any reliable improvements when working memory training was compared with a treated control condition. Furthermore, mediation analyses indicated that across studies, the degree of improvement of working memory measures was not related to the magnitude of far-transfer effects found. Finally, analysis of publication bias shows that there is no evidential value from the studies of working memory training using treated controls. The authors concluded that working memory training programs appear to produce short-term, specific training effects that do not generalize to measures of "real-world" cognitive skills. These results cast serious doubt on the practical and theoretical importance of current computerized working memory programs as methods of training working memory skills (Melby-Lervåg, Redick, & Hulme, 2016). Similar results have been shown in other fields as well: improvement of trained components of cognitive function, but no far transfer effect in experiments about gamified visual training (Duyck & Op de Beeck, 2019) and about near-and far-transfer effects among children's executive function skills (Kassai, Futo, Demetrovics, & Takacs, 2019).

Thus, the idea of improving some abilities through the training of other abilities proves to be futile according to the results of modern research, based mainly on magical thinking and myths. It is doubtful that audio stimulation can improve communicative skills or that a sequence of simple movements can solve problems of reading, writing or calculating.

In the neuropsychological approach to correction and rehabilitation developed by A. R. Luria the whole activity is in the focus of attention and not a specific component.

> The aim of rehabilitation is functional reconstruction of the activity. After determining which links of the activity are disturbed, we try to determine which links remained untouched. In treating the disturbance, we try to use the remaining links, which we supplement with external aids to reconstruct the activity on the basis of a new functional system… During

> the process we try to find ways to give the patient as much feedback as possible concerning both the defect and its effect on the patient's actions. (Luria, 1979, p. 144)

Thus, the patient takes an active part in the process of achieving independent activity, without external help. Raising the activity to a conscious level the patient has an opportunity to develop new skills for problem solving to replace the lost ability.

When we undertake to assist a child struggling with learning problems, we also aim to develop additional skills (reading, writing, calculating) which later will become the basis for more complex cognitive activities. The main principle of neuropsychological correction is to help create a functional system for these skills, using strong components and finding an adequate replacement for the weak ones. In other words, we work with the complex activity instead of training nonrelated or weakly related skills.

The optimal organization of communication within the therapy group provides the conditions for the mobilization of creative activity in the patient's mental sphere, and personality and aids the growth of one's "mental growth" and self-perception. "The internal (the subject) acts through the external and in doing so, changes itself" (Glozman, 2004, pp. 148–149).

Returning to the musical myths, we can agree with Lauren Harris, that criticizing the myth of the Mozart effect we do not mean that music does not have importance for people of all ages.

> If it has not yet managed to enhance our ability to reproduce (I do not know of any reports that it improves fecundity), there are abundant signs that it can promote our learning and well-being in many other ways. For the vast majority, music surely does have strong hedonic powers — it does bring great pleasure… Music fattens neither the body nor the brain… It is not a panacea, an answer for every need or every individual, but what it can do seems reason enough to make it an integral part of our education and life experience. (Harris, 2019, pp. 131–132)

But references to neuroscience and the brain now crop up regularly in academic and pedagogical literatures in early childhood music education. Educators concerned about this recent "brainification" (a term coined by Vandenbroeck in 2014) of early childhood music education point out problems and pitfalls that can arise from this current enthusiasm for neuroscience narratives (Young, 2020).

Conclusion

In this paper we analyzed as an example only some of the most popular neuromyths that continue to influence people who do not have enough knowledge about brain anatomy and functions. It is especially important to increase caution in dealing with neuromyths because they are detrimental and persistent in education worldwide. *Brain-friendly* *learning* is a new trend in school and university instructional practice. It can be seen that some myths are a result of careless analysis or presentation of experimental data by the researchers who then continue to produce new myths. We can love music, but our belief that music is enriching does not mean that listening to music promotes development of intelligence, especially if it is overused as a replacement for communication with a devoted parent or babysitter.

We can only emphasize the need of inclusion of neuropsychology as a compulsory course in teacher education. We consider a wider popularization of the Lurian systemic-dynamic approach as a kind of intellectual immunization against the spreading of neuromyths.

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